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Incorporating Life Cycle Costing in Early Product Design

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Abstract: Life cycle costing (LCC) is a useful and important tool within the design process. In the early design phases of a product life cycle, there are a large number of uncertainties in cost, such as which product to design and how to go about manufacturing it. This paper shows that LCC helps to quantify design ideas to give an indication as to which ideas should be pursued further. It allows the company to have a good understanding of the costs involved in the life of the product they are designing as the analysis provides a framework for specifying the estimated total incremental cost of developing, producing, using and retiring a particular item. In addition, a case study has been used for illustrating life cycle costing in early design phases.

Keywords: Life cycle costing; Product design and development; Search field.

1. Introduction

The product life cycle as shown in Figure 1 is the sequence that a new product progresses through, from the introduction stage, through growth, maturity and eventually decline against the sales expected at each stage [1, 2]. The cycle is associated with changes in the marketing situation, thus impacting the marketing strategy and the marketing mix.

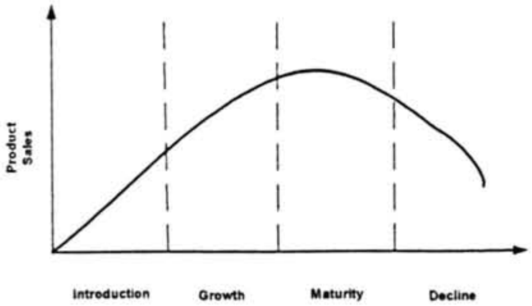

Figure 1. Product life cycle

As between 70% to 80% of the total life cycle cost of a product is committed at the early design stage [3], designers are in a position to substantially reduce the life cycle cost of the products they design, by giving due consideration to the life cycle cost implications of their design decisions [4, 5, 6, 7].

Life cycle costing [8, 9, 10, 11] is the economic assessment of all money flows that are caused by the existence of a product. The Society of Automotive Engineers has a life cycle costing model [12] as shown in Figure 2. It includes acquisition costs, operating costs, scheduled and unscheduled maintenance costs, and conversion and decommissioning costs. LCC are summations of cost estimates from inception to disposal for both equipment and projects as determined by an analytical study. The annual estimated total costs will increase during the product life with consideration for the value of money over time. The goal of LCC analysis [13] is to choose the most cost effective approach from a series of alternatives to achieve the lowest long-term cost of ownership [14]. LCC can be used as a management decision tool for harmonizing the never-ending model conflicts by focusing on facts, money and time. The facts refer to the predictable product and process models that can be obtained from previous projects and research that have been undertaken. Money model comes from cost analysis while the time aspect model looks into the time estimation involved in design, manufacturing and the overall product lifecycle phases. These aspects will be discussed and a compromise reached to decide which product design should go ahead.

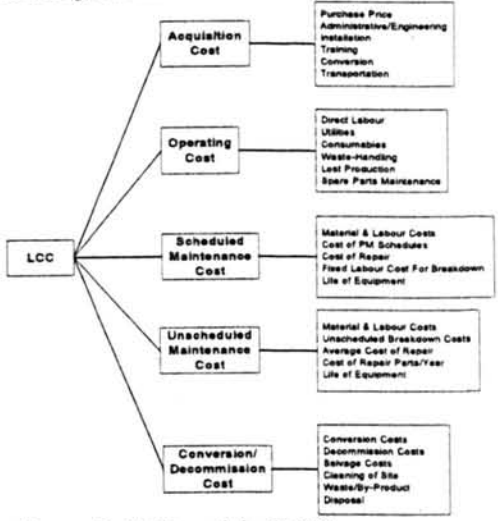

Figure 2. SAE model of LCC

Successful new product development requires the ability to predict, early in the product development process, the life cycle impacts of a product design [15]. The estimating method, such as parametric estimating [16, 17] in early design processes, has been required because of the lack of both detailed information and time for a detailed LCC for a various range of design concepts [18]. Estimating at this stage involves investigating what the product will cost in terms of how much work is required and how long the design and production will take.

Table 1 shows many of the different cost factors that need to be taken into consideration when compiling LCC. The LCC of a product is determined by aggregating all the LCC factors.

Life Cycle	Cost Factor
Design Stage	Market recognition, Product Development
Production Stage	Materials, Energy, Facilities, Wages, Waste, Pollution, Health damages
Usage Stage	Transportation, Storage, Waste, Breakage, Warranty/Service, Energy, Materials, Maintenance, Pollution, Health Damages
Disposal/Recycling Stage	Disposal/Recycling Dues, Energy, Waste, Disposal, Pollution, Health Damages

Table 1. Cost Factors

2. Cost Involved in Early Design Stage

2.1 Cost as an independent variable

The life cycle cost of a product is made up of the costs to the manufacturer, user and society. The total cost of any product from its earliest concept through to its retirement will eventually be borne by the user and will have a direct bearing on the marketability of that product. Cost estimating is very important and is usually done by professional estimators. In a competitive situation, if a company's estimate of its costs is unrealistically low, then it may obtain an order but risks making a financial loss. On the other hand, an overestimate will cause the company to lose orders.

Costs occur in every stage in the product life cycle. There may be one-off costs such as procurement, initial training of staff, documentation or facilities. There may be recurring costs such as operating costs, service charges, downtime or maintenance.

A costing method used is cost drivers, which are parameters of the product that are directly measurable. A cost driver for an organizational activity is the single factor that most influences an individual to spend more or less time on that activity. Every activity is primarily influenced by one of five cost drivers: complexity, novelty, volume, resources and location. In a process with high volumes of repetitive work, volume is the primary cost driver. It indicates that there is a low degree of variability in processing the work. If the other four cost drivers are significant influences on major activities performed, they represent opportunities for work simplification and cost reduction. Overhead costs are added to direct costs in proportion to the drivers.

Cost as an independent variable aims to reduce product life cycle costs. This is achieved through establishing and adjusting programme cost objectives through the use of cost performance analysis and trade-offs. It then executes the programme in a way to meet or reduce the stated cost objectives [19]. A life cycle cost model provides an objective basis for evaluating design alternatives from a very early stage in the development cycle. The cost model has to be evolved. Initially, it will look at operation cost, product price and the project bid to determine what financial implications these will have. It then decides whether to commit or stall the next stage of the design process. It will be based primarily on characteristics of the product design with relatively little consideration of the actual manufacturing process. In the next iteration, e.g. later in the development cycle, a different type of product cost model will be used that will consider the specific manufacturing processes. Cost data for many purchased parts and sub-assemblies will also need to be obtained.

2.2 Life cycle cost analysis

Initially, a plan needs to be created which addresses the purpose and scope of the cost analysis [20]. Its aim is to help management decisions. This plan then needs to be developed into a Lifecycle costing model by adopting a cost breakdown structure. A cost breakdown structure (CBS) is central to LCC analysis. It will vary in complexity depending on the purchasing decision. It should include all cost elements that are relevant to the option under consideration. The cost elements should be well defined and identifiable with a significant level of activity. The cost breakdown should be structured to allow analysis of specific areas; e.g. the purchaser might need to compare prices of spare parts for different options, therefore these costs should be identifiable within the structure. Once the data has been obtained, cost estimates can be developed and then applied to the model. This model could be validated with historical data. The model then needs to be reviewed to ensure that it is adequate for its purpose. The model is then used as a tool which can control and manage the ongoing costs of a product. It allows continuous monitoring of the actual performance during its operational processes [8].

3. The Design Process

3.1 The process

The product design process is a series of tasks that must be completed in order to have a product ready for the market. Figure 3 is a standard design process. It starts with set up a design objective and then goes through the different design phases and finally come up with a detailed product design.

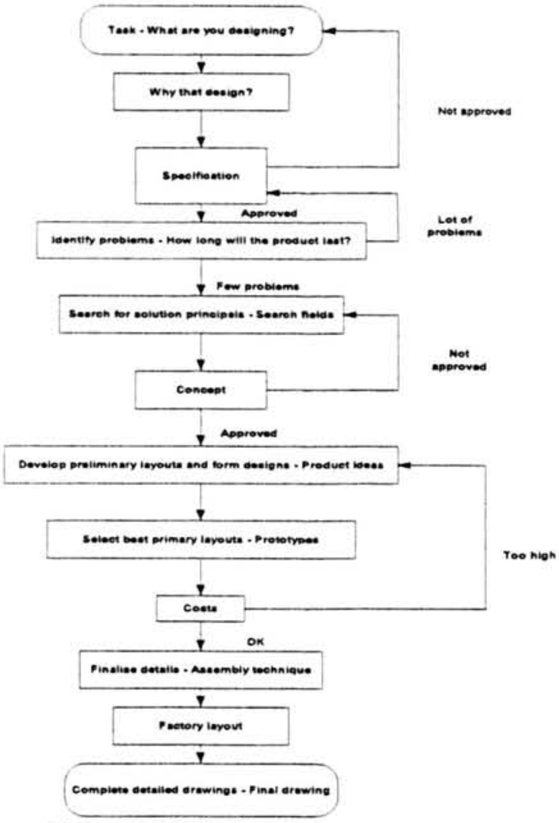

Figure 3. The design process

A product engineer's job is to ensure the customers' needs are satisfied throughout the product's whole life cycle. The task is initially broken down into a similar list of processes as described above. However, the engineer follows the product through its whole life. When the product has been launched, the product engineer assesses the performance by measurement of technical performance. This then allows the product to be re-evaluated and continually improved throughout its lifecycle [21].

3.2 What are you going to design?

Before diving into the design process, a company needs to decide what type of product it is going to design. Will it complement a product that they already make, or will it be completely different? The company needs to look at a broad range of ideas taking into account time commitments, costs, production volumes and sales lifetimes.

Most people without experience in product development are surprised by how much the time and money required to develop a new product. Table 2 [22] provide useful data on development time, development costs, and the numbers of development personnel for a set of different products manufactured in different volumes. This would have an influence over the scale of the manufacturing operation and the size of the factory. The lifetime would have an impact over how well the product needs to be made. In the case of the printer, its life is very short and therefore does not need to be made to last, as it will be superseded by a better model. If it takes a long time to develop a product, such as an airplane, a substantial amount of money must be available (development cost), as it will be a long time before the company begins to make a profit. The number of people working on a project will affect the wages bill that the company will have to pay. When planning which product to develop, all of the above considerations need to be taken into account and compared with the company's aims and financial standing before deciding which product to go ahead and design.

	Screwdriver	*Printer*	*Airplane*
Size of product	**Small**	**Medium**	**Large**
Annual production volume	100,000 unit/year	4 million units/year	50 units/year
Sales lifetime	40 years	2 years	30 years
Development time	1 year	1.5 years	4.5 years
Development cost	$150,000	$50,000,000	$3 billion
No. of people involved	6	175	16,800

Table 2. Attributes of three products and their associated development efforts

The design process involves applications of technology for the transformation of resources, to create a product that will satisfy a need in society. The product must perform its function in the most efficient and economic manner, within the various constraints that may be imposed. The major constraint is cost, although other factors such as safety, pollution and legal requirements will have to be considered.

When a product is being designed, the company needs to decide how long they would like the product to last. The design teams then have to try and adhere to this, but ultimately, the length of time a product will last will be dictated by the designers as they decide how and with what materials the product will be made. They need to look at the proposed lifecycle of the product and also the price they intend to charge the customer. If the product has a short lifecycle, it is uneconomical for the design team to spend lots of money on producing the product out of expensive long lasting materials. Conversely, a consumer would not expect an expensive long life product to break within a month of usage. It is a difficult balance for designers to achieve.

3.3 Search fields

Search fields are a useful tool at the beginning of the design process. The spider diagram (Figure 4) gives a clear overview of all the areas that need to be considered when designing a product.

Market: to ensure that you are producing the correct product, in the correct quantities and at the correct time.

Economic: to discover if the raw materials can be purchased abroad or the final product can be sold abroad.

New technologies: to investigate if there are new technologies which would make the production process more efficient.

Laws: to ensure that the manufacturing plant and the product conform to regulations.

Other: factors such as population growth which will affect the size of the market.

Using the search fields helps to ensure that every design aspect for the product is investigated in the early design phase. Companies do not want to discover expensive problems when the product is in the manufacturing stage nor when the product has been sold.

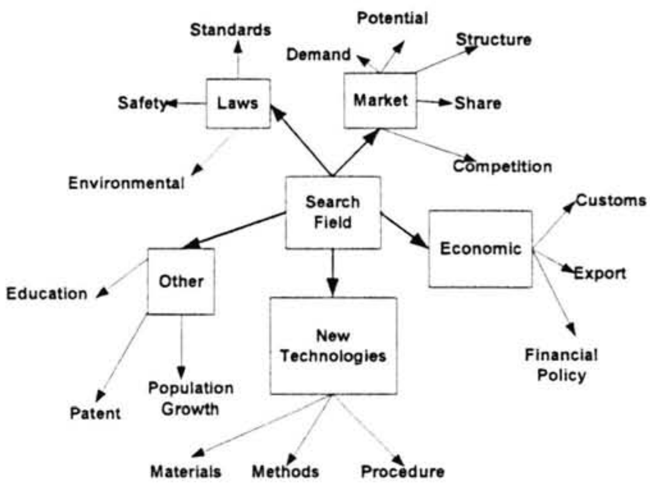

Figure 4. Search fields

3.4 Design for cost

This technique challenges proposed designs and could lead to a reduction in product cost of around 50%. This is achieved through value engineering and analysis, optimizing manufacturing methods and location, global component sourcing and advanced materials and manufacturing techniques [23].

For products with relatively little user interaction such as industrial equipment, the cost of design is in tens of thousands of pounds. The development of an intensely visual and interactive product such as a car requires millions of pounds of design effort. The relative cost of design as a fraction of the overall development budget also shows a wide range. For a technically sophisticated product, such as a new aircraft, the design cost can be insignificant relative to the engineering and other development expenditures [22].

The cost of product development is roughly proportional to the number of people on the project team and the duration of the project. In addition to development expenses, a company will have to make some investment in tooling and equipment required for production. This expense is often as large as the rest of the product development budget.

Throughout their lifecycles, certain products may incur some company or society costs which are not accounted for in the manufacturing cost, these costs must be decided in the design stage. For example, products may contain toxic materials requiring special handling in disposal. Products may incur warranty and service costs.

3.5 Product ideas

Many product ideas will come from looking at the search fields. As different ideas are explored, they may be developed further or written off from the information found from the search fields. Once the designers have a range of designs to be considered, they get together with both the management and production teams to decide which design will go forward to become the finished product that will be sold. The pros and cons of each design need to be considered before a decision is made as to which design will go forward to be made into a prototype. A product cost model is used to accumulate product costs to use as a factor in evaluating design alternatives and to redefine the design to meet cost targets. If it is determined after extensive evaluation that the product requirements cannot be achieved at the target cost, the requirements and targets will need to be re-evaluated and modified.

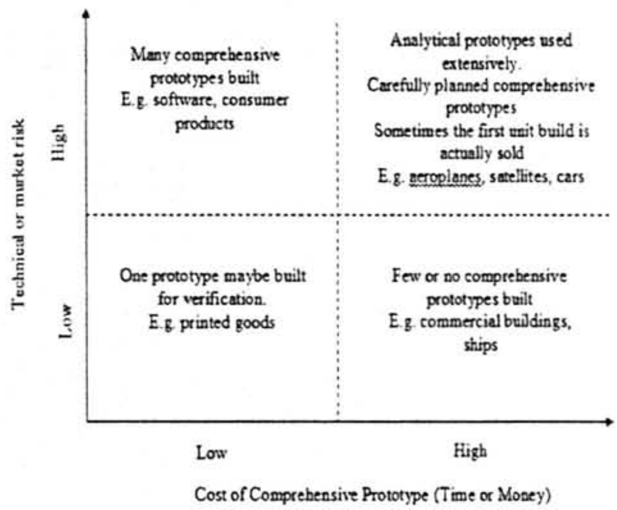

Figure 5. The use of prototypes

Prototypes are very useful as they can be used to learn whether the design will work and whether it will meet the customers' needs. They are useful for enriching communication with top management, vendors, partners, customers and investors. Once they can actually see the product, it is much easier to visualize if it will be successful. Prototypes also give the production team a chance to discover if the components and subsystems of the product work and fit together as proposed. It is also an opportunity to see how well the budget for the product is being kept, and whether there is a need to make any necessary alterations and adjustments.

The use of comprehensive prototypes depends on the relative level of technical or market risk and the cost of building a comprehensive prototype. This is displayed below in Figure 5. For example, if your product has a high market risk and the cost to create a prototype is low, it is likely that many prototypes will be built to ensure that you are producing the optimum design for the customer (e.g. consumer products). However if your market risk is low and the cost to build a prototype is very high (e.g. a building), it is unlikely that a physical prototype will be built.

4. The Case Study – Light Bulbs

4.1 Market research

From a design concept to the product entering the market costs a considerable amount of money. It is therefore important that the company conducts sufficient research into customer requirements before committing the time and money required to design the product. The research will look at the existing products on the market, and how they could be modified to suit the proposed customer. One of the best ways to find out what the customer requires is to ask them what they would like to see in a new product. Conducting market research prior to the main design stage is very useful, as the designers are then aware of their intended market and the markets view on that product so that they can be incorporated into the design.

A light bulb customer questionnaire was compiled by means of mail, email and personal interview etc to discover the needs and requirements of customers across the generations. A copy of the complete questionnaire is added as the appendix. Sixty questionnaires sent out and fifty questionnaires answered. It was given to people of all ages to complete to gain the full spectrum of requirements in the product. The main questions in the questionnaire included:

- How much are you happy to pay for a bulb?
- Where do you buy your bulbs from?
- What wattage bulbs do you buy?
- Do you buy energy saving bulbs and what would entice you to buy more?

Based on the results from the questionnaires, the following information was obtained. It showed that on average, the customer is prepared to pay 39p for a standard 60W incandescent bulb. This is an important factor for the design team, as the finished product should aim to fall into this price area, in order to obtain the maximum number of customers. It was also discovered that the majority of people buy their bulbs from supermarkets as opposed to DIY stores. Purchasing a bulb in the supermarket along with their weekly shop is more convenient than traveling especially to a DIY store. Note that expert help would be available in deciding which bulb would be the most suitable for your use from a DIY store, but this is not available in a supermarket. The bulb packaging must contain sufficient information for the customer to be able to make an informed decision as to which product suits their needs.

Figure 6 shows that wattage is the most important specification when a customer buys a bulb. The designers should therefore ensure that they offer a wide range of wattages to offer the customer plenty of choice. Color appears to be the least important factor, therefore only a small amount of money should be spent on color.

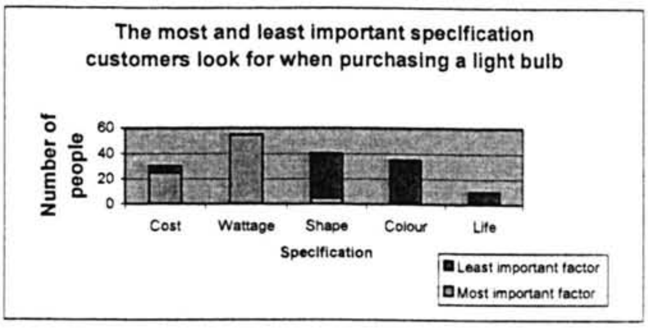

Figure 6. The most and least important specifications that customers look for when purchasing a light bulb

There is a very wide range of light bulbs available on the market today. Table 3 show three different options. The cheapest bulb is incandescent bulb. However, this is a very low wattage bulb. At the other end of the scale, the most expensive bulb found was an energy saving bulb costing £8.98. When comparing this bulb to an incandescent bulb of the same wattage, the energy saving bulb costs nearly 50% more per 1000 hours of light given out. However this does not take into consideration the cost of energy to keep the bulbs lit for this length of time.

	Type	Wattage	Price	Shop	Life cycle	Price /1K hrs
Cheapest	Incandescent	25w	45p	B+Q	1000 hrs	45p
Most expensive	Energy saving	11w	£8.98	B+Q	12000 hrs	75p
Equivalent wattage	Incandescent	60w	50p	Philips	1000 hrs	50p

Table 3. Light bulb prices

Table 4 shows the cheapest energy saving bulb and the most expensive incandescent bulb found. In this instance, the energy saving bulb costs less than half the price of the incandescent bulb per 1000 hours of light. It shows that although energy saving bulbs are the most expensive to purchase initially, they last much longer than incandescent bulbs. Many consumers are aware of this, however, it is still more attractive at the time to buy the cheaper incandescent bulb over the energy saving bulb. Manufacturers need to try to help change this way of purchasing for the benefit of the environment in which we live.

Type of bulb	Wattage	Price	Shop	Life cycle	Price per 1K hrs
Energy Saving	11W	£1.97	Philips	6570hrs	30p
Incandescent	150W	£1.29	Mazda	2000hrs	65p

Table 4. Light bulb comparison

The current policy is to encourage consumers to use energy saving light bulbs, which last longer, use less electricity and are better for the environment. When questioned, the average number of energy saving light bulbs in a home was three, which is a low value. The customers were then asked what would entice them to buy more energy saving bulbs. As the graph below shows (Figure 7), consumers would be more willing to buy the bulbs if they were cheaper and smaller than those currently on sale. These are design specifications from the customer, which the designer should aim to take into consideration during the design process.

When the consumer was asked if they would pay for a more expensive bulb that could be recycled at the end of its life, as opposed to a cheaper one that went straight into a land fill site, the results were split half and half. Half of those surveyed are willing to pay a little more for the product to be recycled; therefore it is worth trying to incorporate how the product will be recycled at the initial design stage.

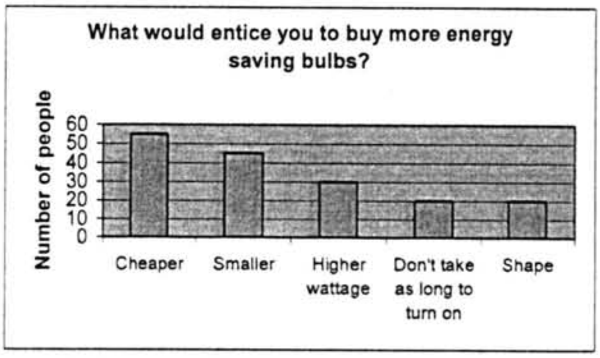

Figure7. What would entice you to buy more energy saving bulbs?

4.2 New technologies

For light to be generated from a bulb, a metal must be heated to extreme temperatures before it will emit a useful amount of visible light. Light bulbs are manufactured with tungsten filaments because tungsten has an abnormally high melting temperature. Tungsten will catch fire at high temperatures, if the conditions are right. The filament is housed in a sealed, oxygen-free chamber to prevent combustion. In a modern light bulb, inert gases, typically argon, are present. This helps ensure that when a tungsten atom evaporates, it should collide with the argon atom and bounce back towards the filament as shown in Figure 8 [24].

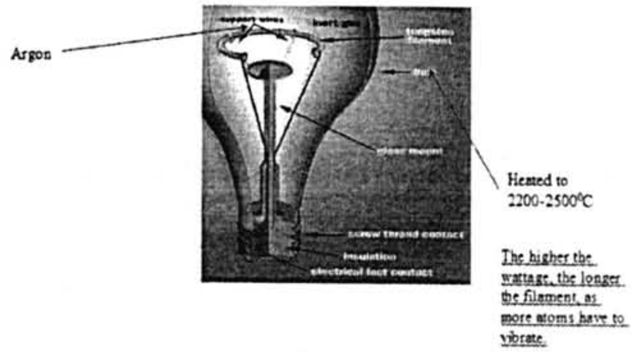

Figure 8. The set up for an incandescent light bulb

Table 5 shows the raw material costs to produce a bulb. This is the cost breakdown structure. The availability of the material, the quantity per unit time, remembering losses due to handling, storage and process waste and the quality of the raw materials, all need to be taken into consideration. In total, the cost of raw materials per bulb is equal to 40p.

This appears to be very high, considering most incandescent bulbs are sold for less than £1. In a manufacturing plant, the company would be able to order their raw materials in much larger quantities, therefore costing them less per bulb.

Material	Units of Purchase	Cost	Amount per bulb	Cost per bulb
Tungsten	1000m	£35	0.5m	7p
Argon	$0.566m^3$	£43	$5.32x10^{-5}m^3$	0.004p
Glass	$2.9x10^{-3}m^3$	£10.20	$5.32x10^{-5}m^3$ (hollow)	18p
Bulb base	304mm	£2.86	15mm	14p
Others	Wiring and fuses	Small		≈ 1p

Table 5. Cost of raw materials for a bulb

Tungsten is the raw material which dictates the life of the product. When the tungsten filament blows, the bulb is towards its end of life. Therefore, if the lifecycle of the tungsten is 1000 hours, the glass, argon and bulb base need to have a lifecycle which is longer than this in order for the bulb to satisfy the anticipated bulb lifecycle.

In the case of light bulbs, recent product development has led to improvements in halogen bulbs. Standard incandescent light bulbs have been sold for over one hundred years, and during this time they have developed very little. However, they are very inefficient (10% light, 90% heat) and have a life of only 1000 hours. If a light bulb was designed which was more efficient and lasted longer, it should generate greater sales and be more successful.

This is where the halogen bulb has been developed and improved light bulb efficiency. A halogen lamp uses a tungsten filament, the same as an incandescent bulb, but it is encased inside a much smaller quartz envelope. As the envelope is so close to the filament, it would melt if it were made from glass. The gas inside the envelope is from the halogen group. If the temperature is high enough, the halogen gas combines with the tungsten atoms as they evaporate and redeposit them on the filament. This recycling process lets the filament last longer. Also, it is now possible to run the filament hotter, which means you get more light per unit of energy. It still gives off a lot of heat because the quartz envelope is so close to the filament. It is extremely hot compared to a normal light bulb. Halogen bulbs can last up to four times longer than a standard bulb, and can cost between 89p and £2.25 for a 50W bulb, depending on size and shape [24].

5. Conclusion

It can be seen that to release a product successfully onto the market takes a considerable amount of time, effort and money from the company involved. It is important that they have sufficient planning and organization early in the design process to ensure a successful output. LCC is very important in the decisions that are made with regards to which product to manufacture. It is used to select between product alternatives.

Light bulbs are a product used by millions of people all over the world, with everyone having their own specific requirements as to shape, wattage, color and price. It is difficult for manufacturers to be able to adhere to all these requirements, particularly as there are now many regulations in place for how companies manufacture. Light bulbs are an established product that have been on sale for over a hundred years, but in the future, the manufacturers need to produce more variety of bulbs as customer demands change. This paper suggests that with LCC analysis, customers can expect to have more environmentally friendly, less costly, and more lasting bulbs.

References

1. Onkvisit, S., Shaw, J. J., 1989, Product Life Cycles and Product Management, Greenwood Pub Group.

2. Hata, T., Sakamoto, H., Kato, S., Kimura, F., Suzuki, H., 1998, "Feasibility study for "rapid product life cycle"", Proceedings of 5th International Seminar on Life Cycle Design, KTH, Stockholm, pp151-160.

3. Ogunlana, O., Thorpe, T., 1987, "Design phase cost estimating: The state of art," International Journal of Construction Management and Technology, Bradford, v2, n4, pp. 34-47.

4. Alting, L., 1993, "Life-cycle design of products: a new opportunity for manufacturing enterprises", in Concurrent Engineering: Automation, Tools, and Techniques, A. Kusiak (ed.), New York: Wiley, pp. 1-17.

5. Dean, E. B., Unal, R., 1992, "Elements of designing for cost", Proceedings of AIAA 1992 Aerospace Design Conference, February, Irvine, CA.

6. Dighton, R. D., 1980, "The hornet program: a design to life cycle costs", Proceedings of the Design to Cost and Life Cycle Cost Around Conference, v289, May, pp.8-1 to 8-12.

7. Ishii, K., 1995 "Life cycle engineering design", Design for Manufacturability, ASME, de-81, pp.39-45.

8. New south Wales Government Asset Management Committee, 2001, Life Cycle Costing Guideline, Series, Asset Management Series: TAM, ISBN: 0 7347 4164 2.

9. Hegde, G. G., 1994, "Life cycle cost: a model and applications", IIE Transactions, v26, pp. 56-62.

10. Barringer, H., P., 2003, "A life cycle cost summary", International Conference of Maintenance Societies ICOMS 2003, 20-23 May Australia.

11. Blanchard, B. S., 1979 "Life cycle costing – a review", Terotechnica, 1, 9-15.

12. Society of Automotive Engineers (3rd ed), 1993, "Life Cycle cost, reliability, maintainability and supportability guidebook", Warrendale:PA.

13. Lee, D., Melkanoff, M. A., 1993,"Issues in product life cycle engineering analysis", ASME Conference on Design Automation Conference, pp. 75-86.

14. Barringer, P., 2004, "Life cycle cost analysis – who does what?" Maintenance Conference and Exhibition, National Petrochemical & Refiners Association, 25-28 May, San Antonio, Texas, pp. 1-9.

15. Fabrycky, W. J., 1987, "Designing for the life cycle", Mechanical Engineering, pp. 72-74.

16. Daschbach, J. M., Apgar, H., 1988, "Design analysis through techniques of parametric cost estimation", Engineering Costs and Production Economics, 14, pp. 87-93.

17. Burmeister, M. H., 1980, "Parametric analysis of design to life cycle cost," Proceedings of the IEEE National Aerospace and Electronics Conference, NAECON 80, Dayton, Ohio, 2, pp.675-681.

18. Park, J. H., Seo, K. K., Wallace, D., Lee, K. I., 2002, "Approximate product life cycle costing method for the conceptual product design", CIRP Annals, v51 (1), pp.421-424.

19. Vitaliano, W. J., 2005, "Save 1000 Hours and Promote Cheaper Alternatives", www.galorath.com/customer_case-harris.html

20. Asiedu, Y., Gu, P., 1998, "Product life cycle cost analysis: state of the art review", International Journal of Production Research, 36(4), pp. 883-908.

21. Bahill T., Dean, F., 2005, "What is system engineering? A consensus of senior system engineers", www.sie.arizona.edu/sysengr/whatis/whatis.html.

22. Ulrich, K. T., Eppinger, S.D., 2003, Product Design and Development, McGraw Hill: London.

23. PA Consulting Group, 2005, "Design for cost, meeting the challenge for low cost-base competition without compromising product quality, www.paconsulting.com/NR/rdonlyres.07CFB134-AC44-4170-82EC-DF7E6455CA05/0/rp_low_cost_ccompetition.pdf

24. Harris, T., 2005; "How light bulbs work?" http:science.howstuffworks.com/light-bulb2.htm

Appendix – Light Bulb Questionnaire

1. How much are you happy to pay for a standard 60W bulb? (shop price is approx. 50p)
   0-10p; 11-20p; 21-30p; 31-40p; 41-50p; 51-60p; 61-70p; 71-80p; 81-90p; 91-100p; 101p+

2. Where do you normally buy your light bulbs from?
   Supermarket; Hardware Store; DIY store (e.g. B&Q); Other............

3. Please rank (1-5) what you find most important specifications to look for when buying a bulb?
   Cost; Life; Wattage; Colour; Shape

   Why have you chosen the specific specification as rank 1?

   ....

4. What wattage bulbs do you usually buy? (circle all that apply)
   10W; 15W; 25W; 40W; 60W; 75W; 100W; 150W; 200W; 300W; 500W; Don't know

5. Does the wattage of bulb that you buy vary according to the room for which the bulb is intended?
   Yes No

6. How many energy saving light bulbs do you have in your home?

   ....

7. What would entice you to buy more energy saving light bulbs? (circle all that apply)
   Cheaper; Smaller; Higher wattage; Don't take as long to turn on; Shape; Other:

   ....

8. Which product would you purchase: (Circle the letter)
   a) a 60W bulb which at the end of its life would be returned to the manufacturer for recycling, costing you 60p to buy

   OR

   b) a standard 60W bulb costing you 50p.

   Why?

   ....

9. Do you recycle any of the following products? (Circle all that apply)
   Glass; Paper; Cans; Plastic; Clothing
   If yes, does it cost you anything to recycle them?
   Yes No

   If yes, how much?

   ....

10. Which age bracket do you fit into?
    0-16; 17-25; 26-35; 36-45; 46-55; 56-65; 67-75; 75+